

# Tune-Based Halo Diagnostics

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# *Kinds of Tune-based Tools*

HALO'03

- Tools to **Diagnose** Halo-forming conditions
  - Tools to **Avoid** Halo formation
- Tools to **Diagnose** existing Halo
  - can we see Halo with tune measurements?
  - what are the signatures?
- Tools to **Remove** Halo
  - Gap cleaning
  - Halo cooling
  - ???

# *‘Applicable’ Mechanisms*

HALO'03

## Tune related halo formation mechanisms

- **Mismatch**
- Resonances
- e-cloud effects
- Instabilities
- Beam-beam
- Tune modulation

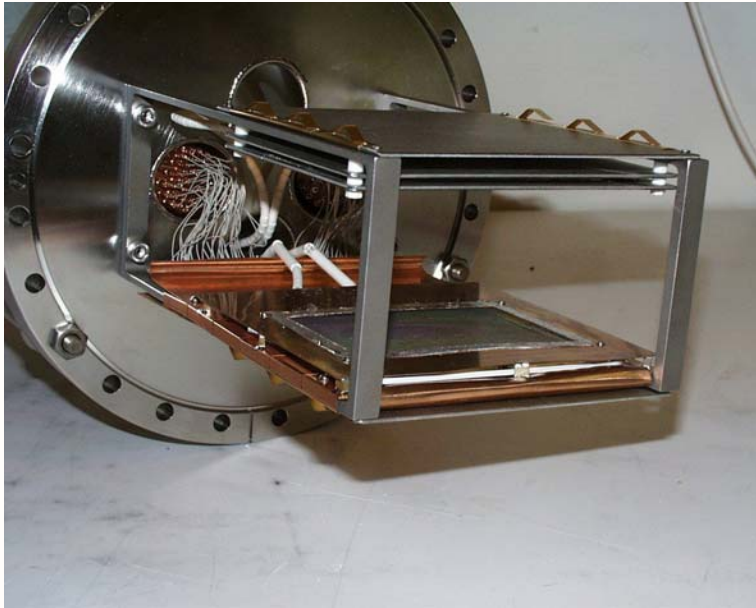
*fast*



*slow*

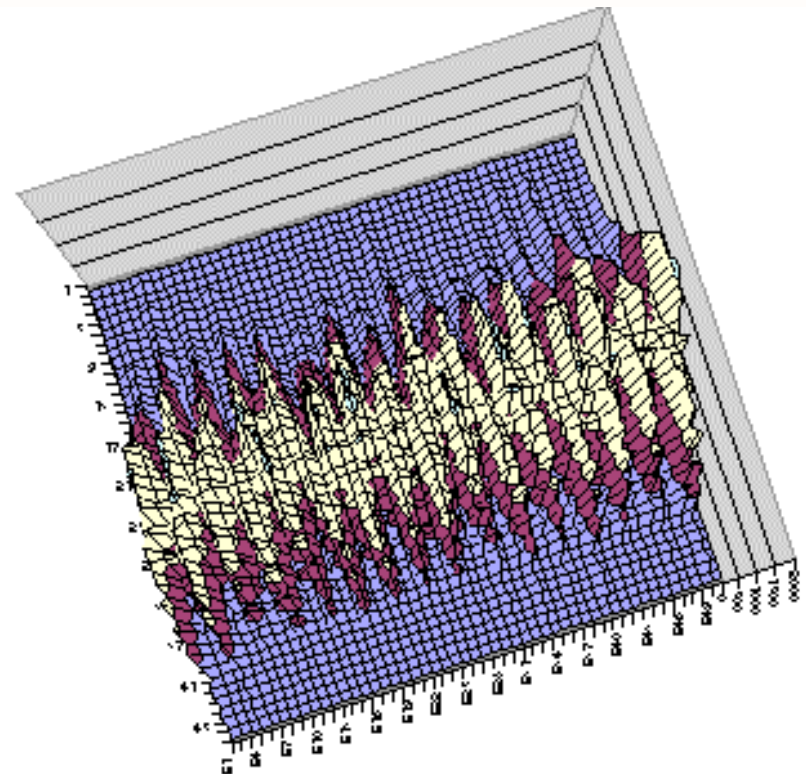
# Mismatch - IPM

HALO'03



Original detector head, before improved image current screening, extended sweep field, moving of components beyond physical aperture

Data from this head, showing turn-by-turn profiles, injection betatron oscillations and quadrupole oscillations

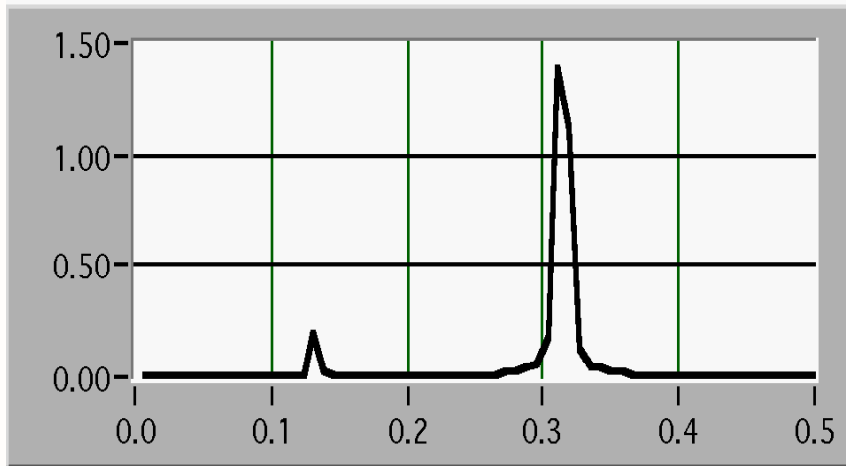


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# Mismatch - IPM

HALO'03

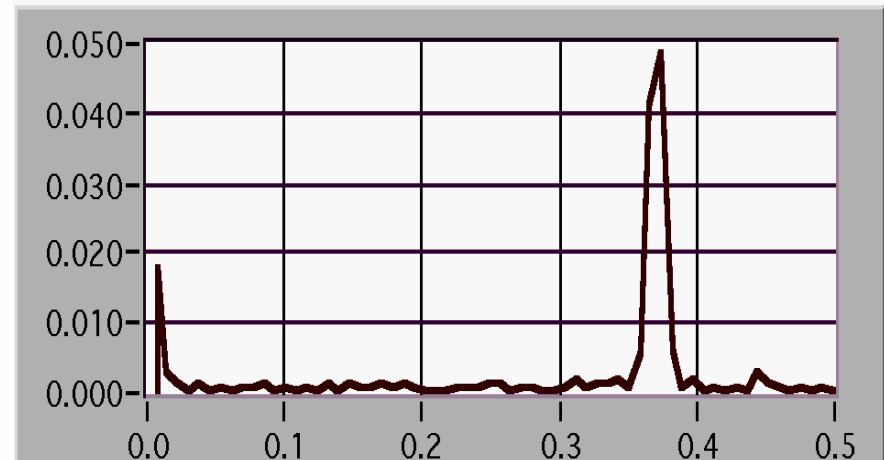
dipole spectrum



Dipole spectrum - FFT of 128 turns of fitted beam position. Data shows vertical tune of 0.32 and horizontal tune of 0.13.

Quadrupole spectrum - FFT of 128 turns of rms beam width. Betatron frequency = 0.32, so quadrupole frequency = 0.64, which appears at the aliased frequency of 0.36

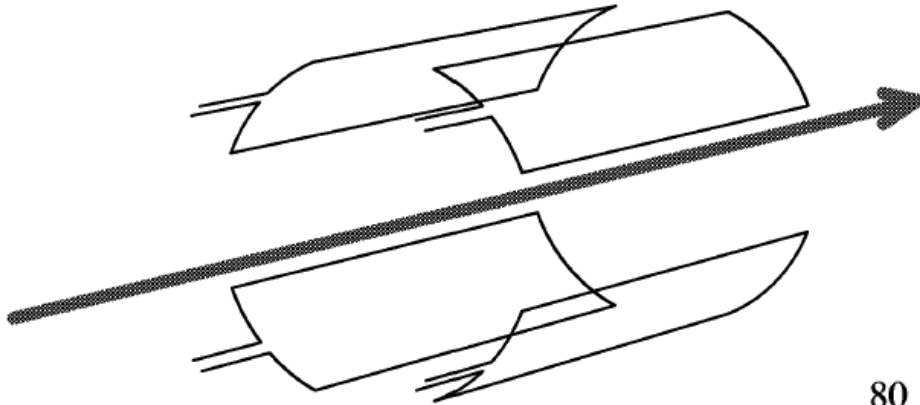
quadrupole spectrum



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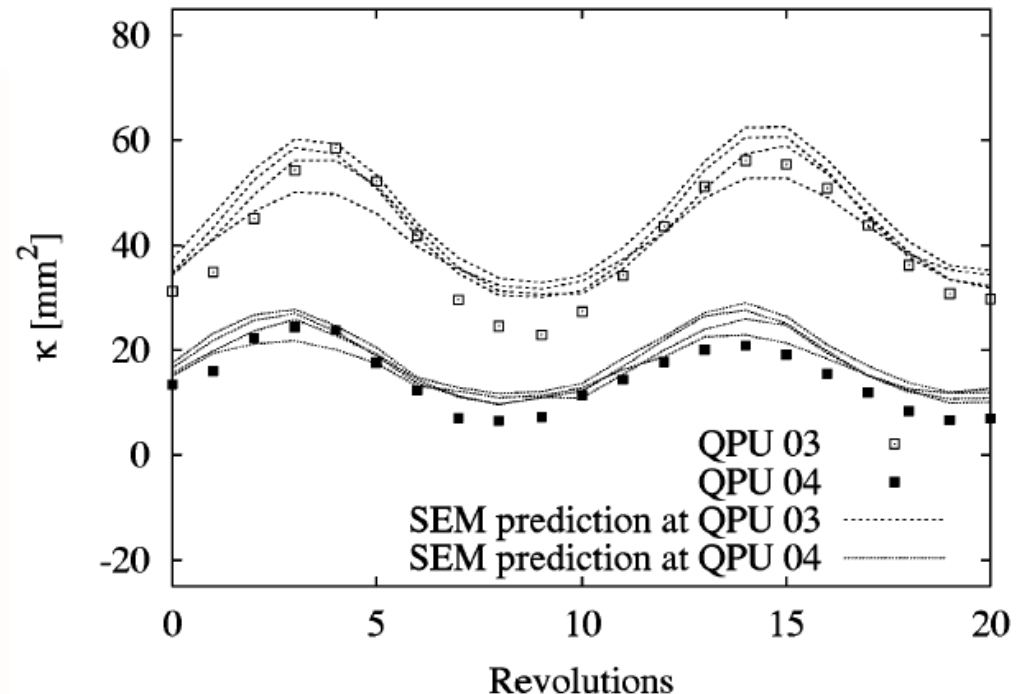
# Mismatch - Quadrupole Monitor

HALO'03



Jansson et al - BIW02  
Loops couple to radial  
magnetic field

Injection oscillations -  
comparison of SEM  
and QMM data

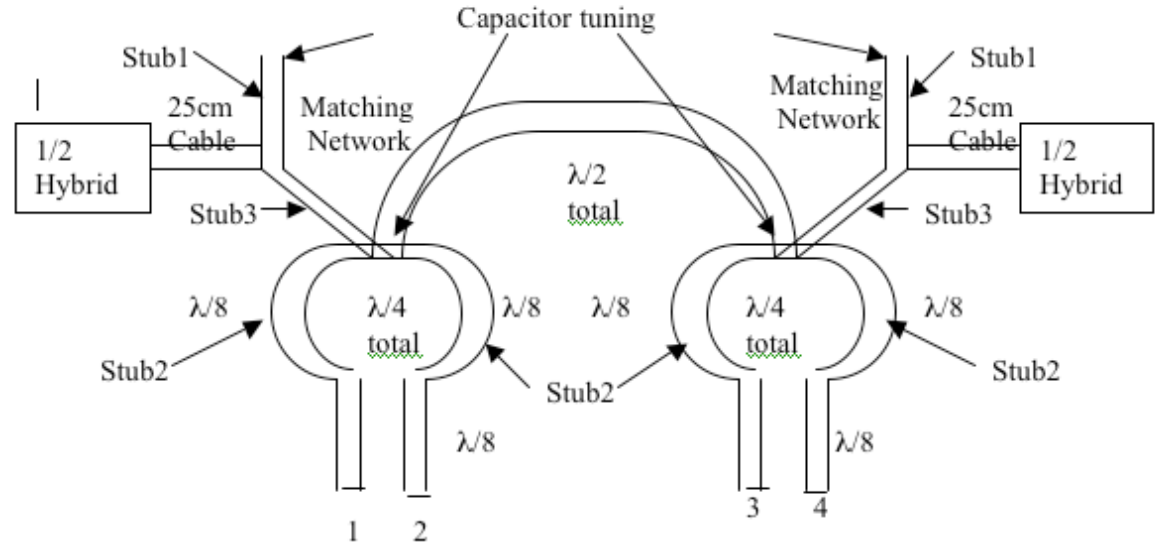


# Resonant Quadrupole Monitor

HALO'03



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General Tuning Scheme

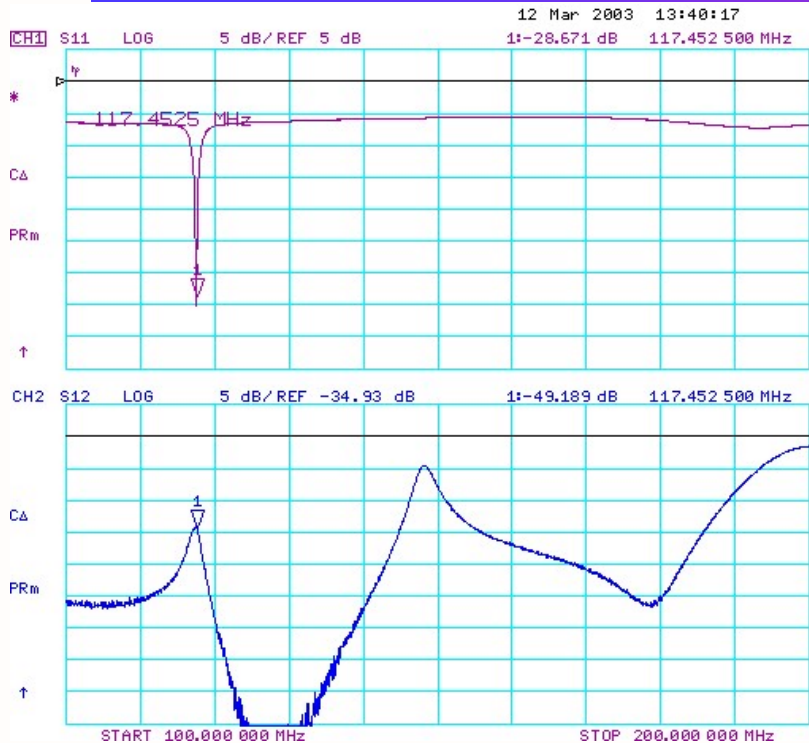
Above - schematic of quadrupole mode resonated BPM

At left - dipole mode transmission-line resonated stripline BPM



# Resonant Quadrupole Monitor

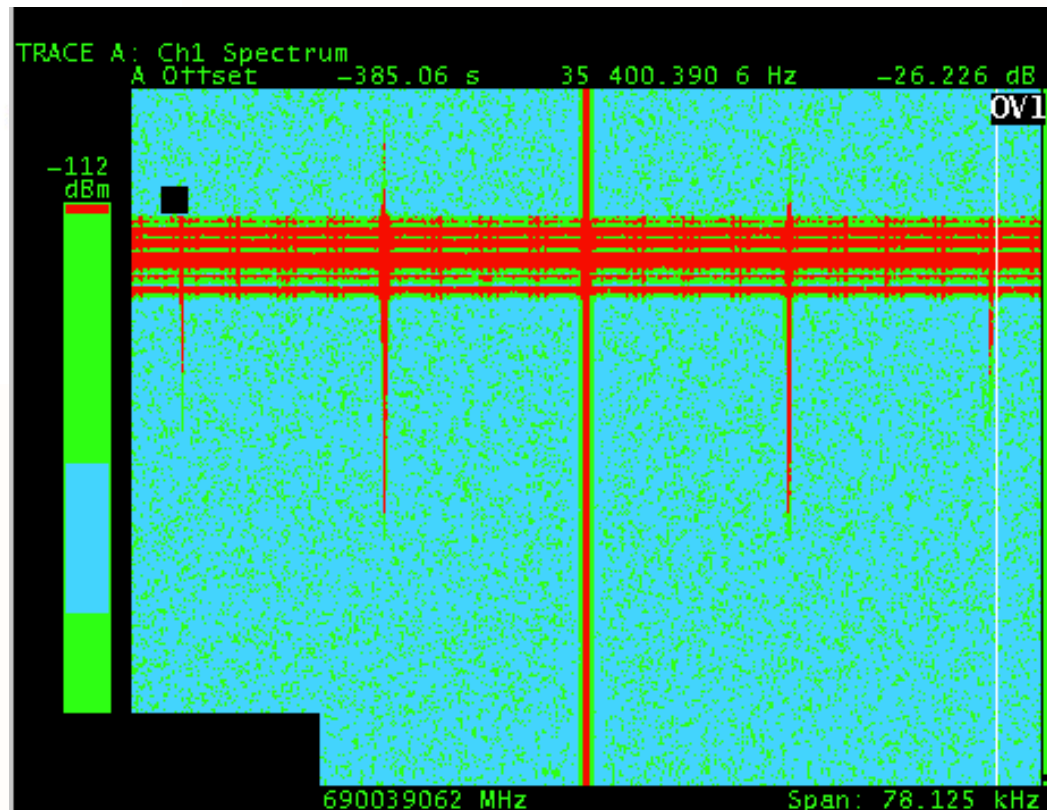
HALO'03



Measured  $Q \sim 60$  at  
108MHz (but large orbit  
offset, 70 degree striplines)

Instability at injection  
- revolution, betatron,  
and quadrupole lines

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# *‘Applicable’ Mechanisms*

HALO'03

- Mismatch
- **Resonances**
- e-cloud effects
- Instabilities
- Beam-beam
- Tune modulation

*fast*



*slow*

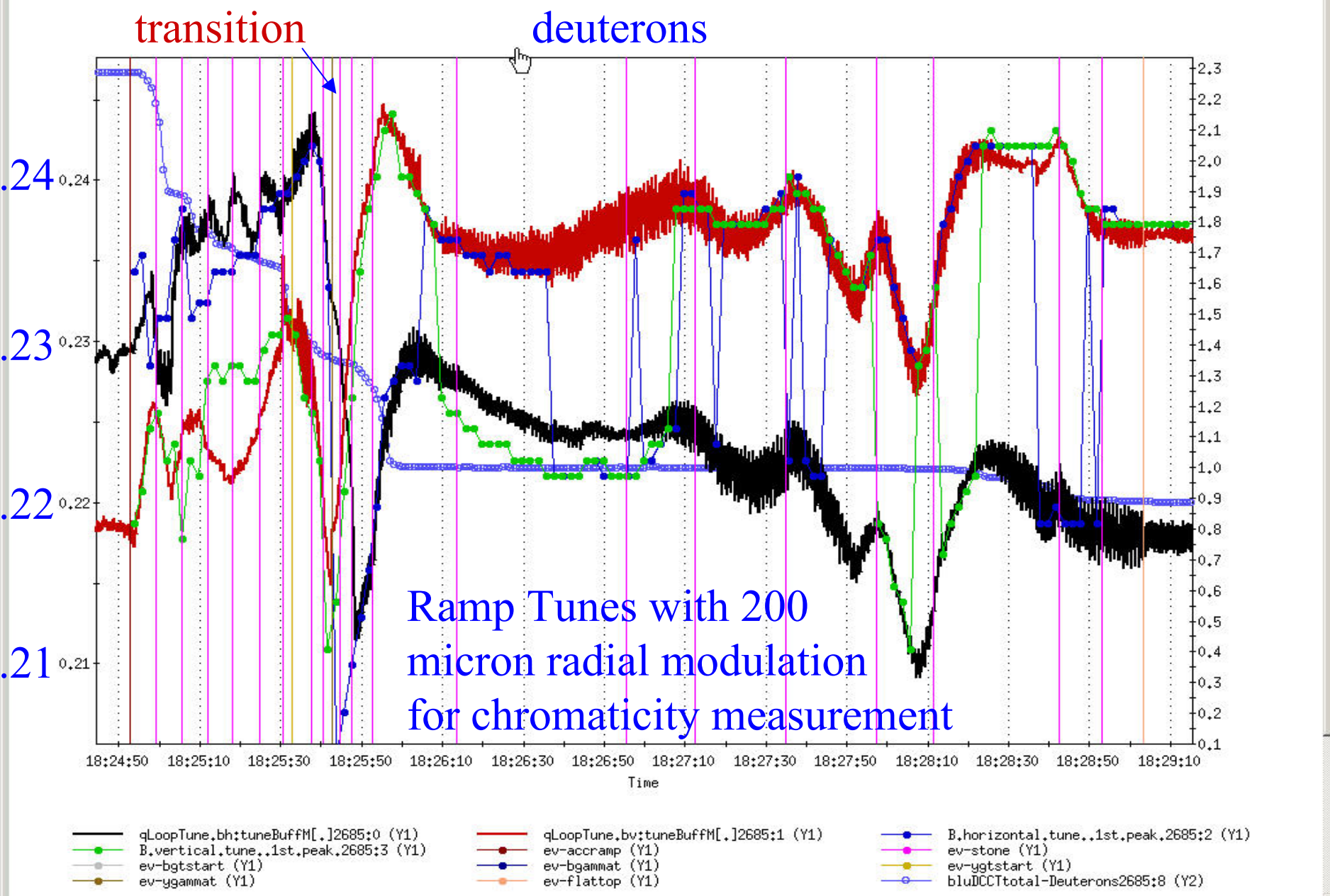
# *Resonances*

HALO'03

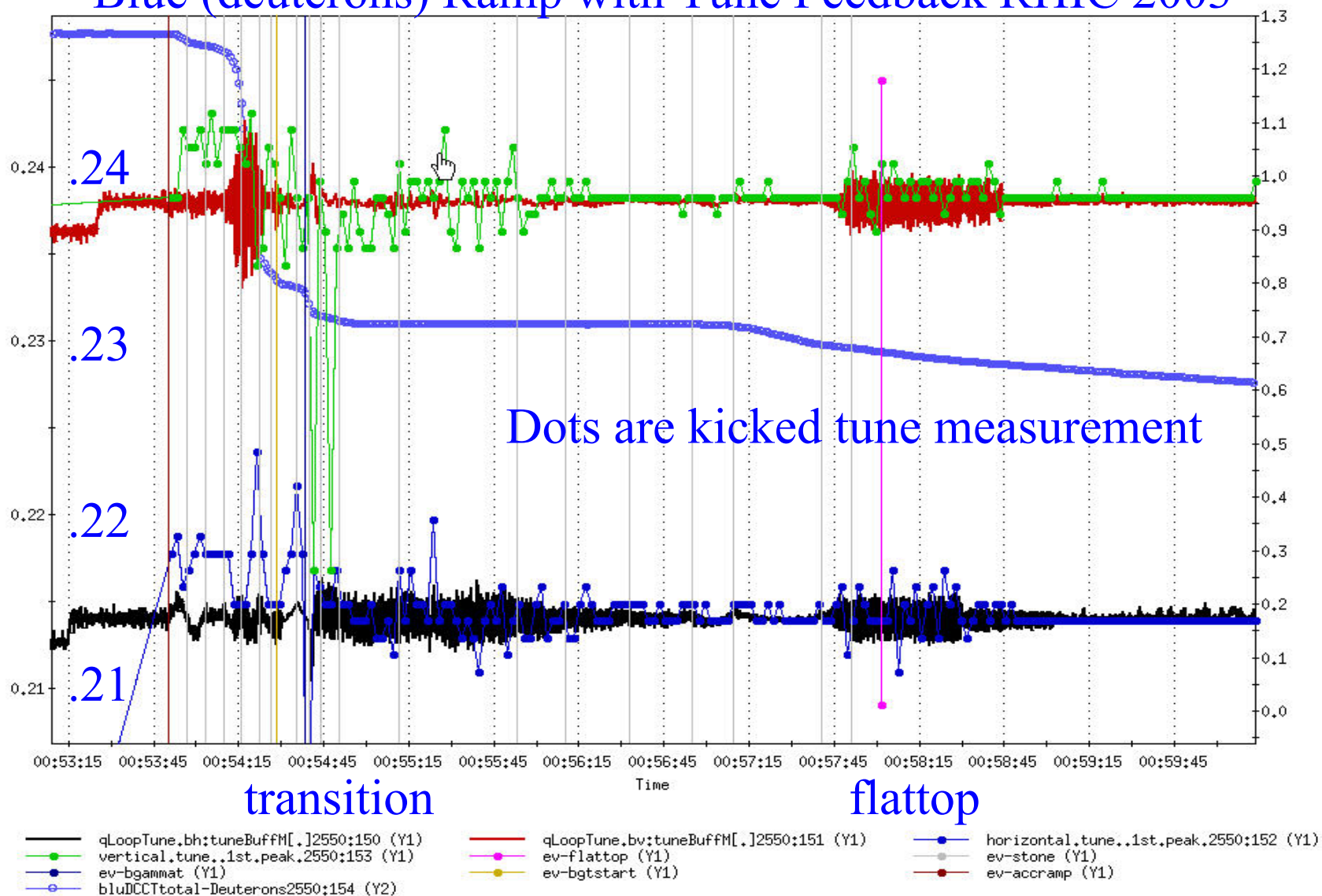
*What drives beam onto Resonances?*

- **Tune**
- **Space Charge**
- Chromaticity (tune spread)
- Non-linearities
- Coupling
- ???

*Islands*

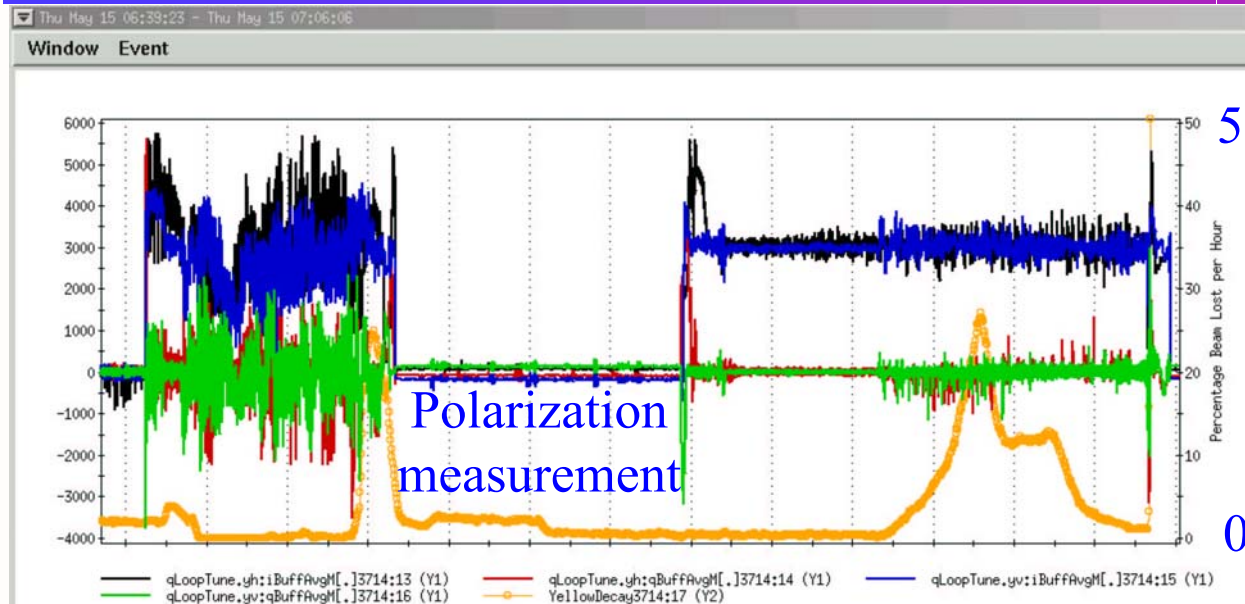


# Blue (deuterons) Ramp with Tune Feedback RHIC 2003



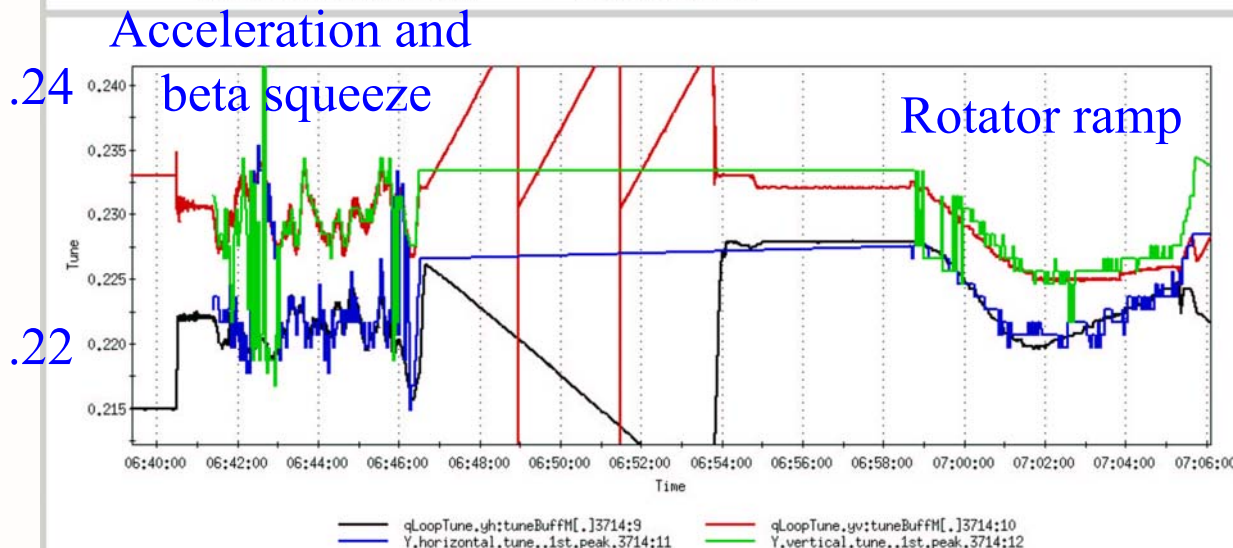
# What about Emittance Growth?

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PLL amplitude and phase, and beam loss rate [%/hr]

Kicker power ~20mW (at store lock is good with 20μw)

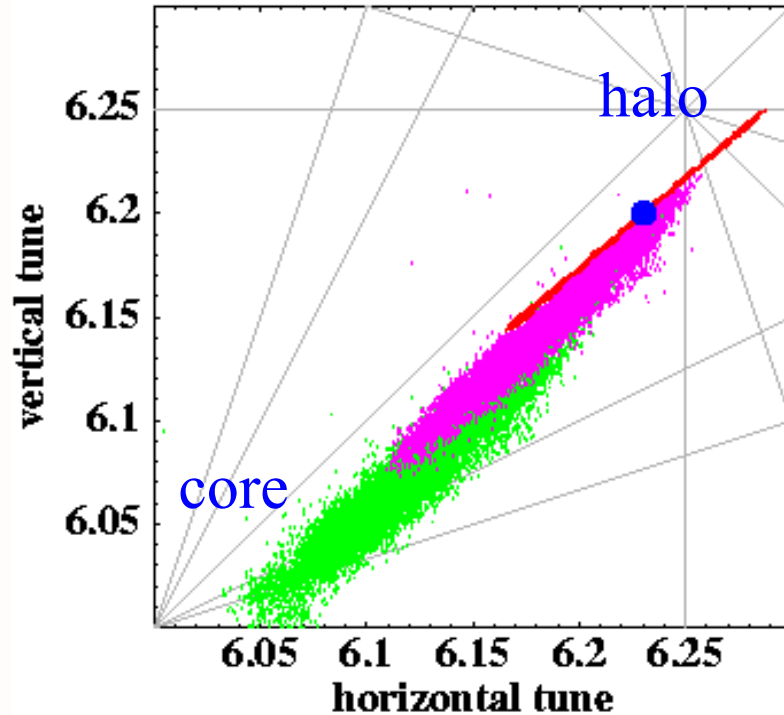


Kicked and PLL tune measurement

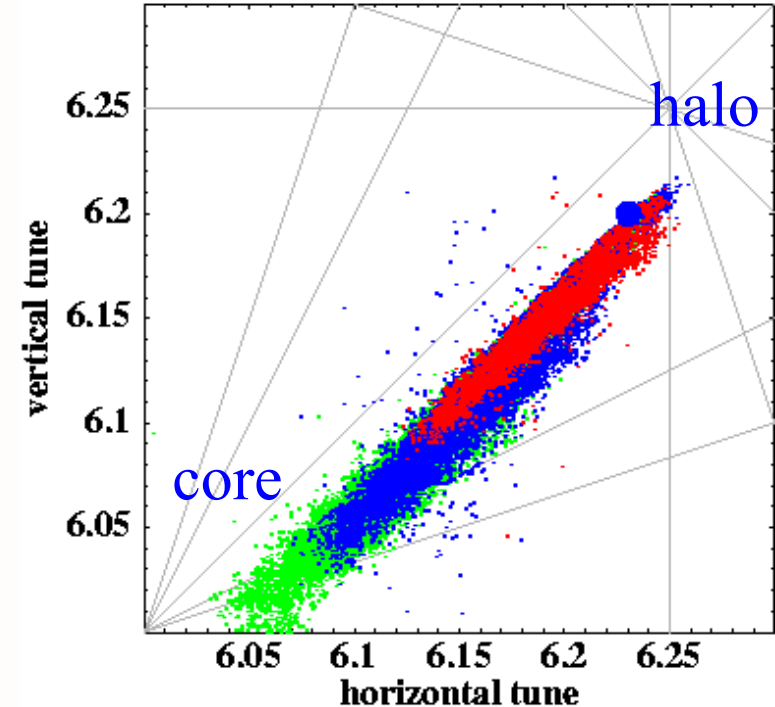


# *SNS Ring Tune Footprints - blue dot is coherent tune*

HALO'03



Footprints for 3 intensities  
( $0.1$ ,  $1$ , and  $2 \times 10^{14}$ ) at cycle end

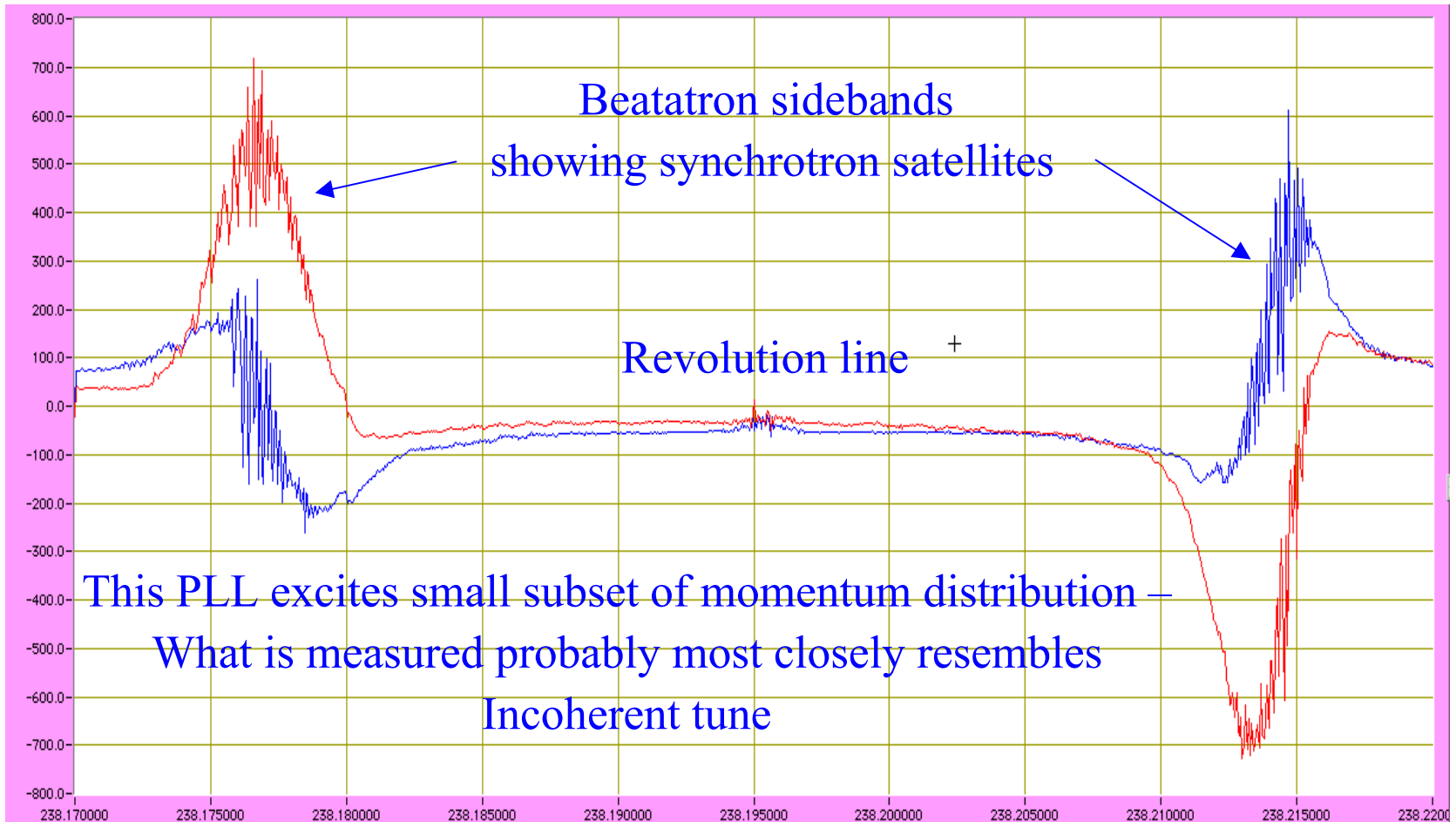


Footprints after 263, 526,  
and 1060 turns,  $10^{14}$  beam



# Beam Transfer Function

HALO'03



# *Resonances*

HALO'03

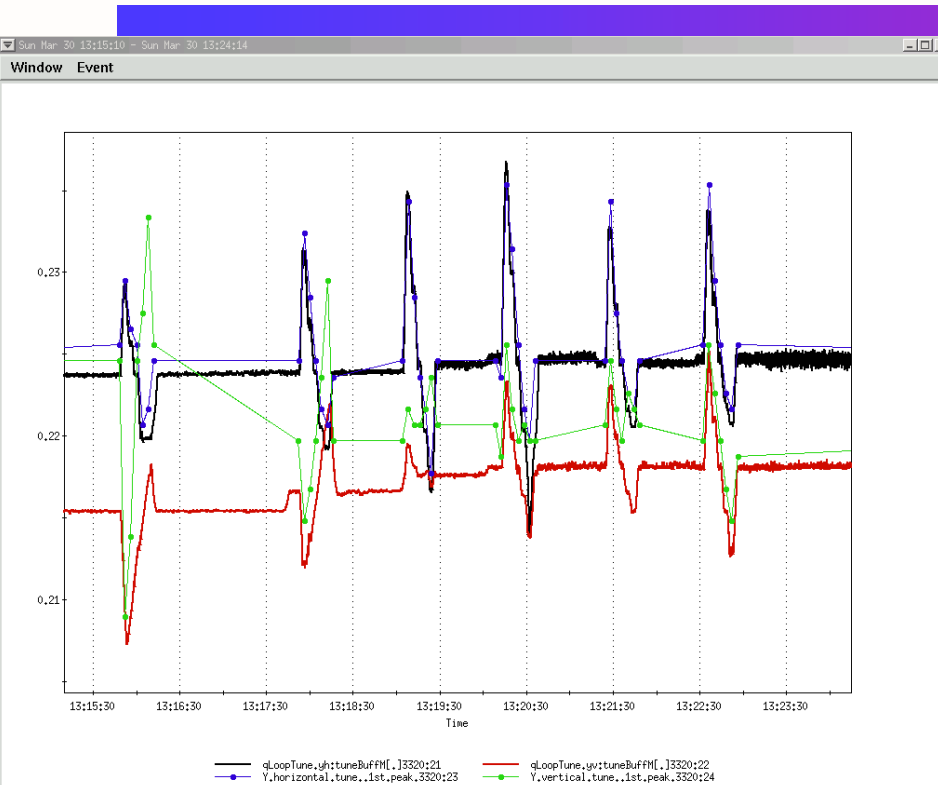
*What drives beam into Resonances?*

- Tune
- Space Charge
- **Chromaticity (tune spread)**
- **Non-linearities**
- Coupling
- ???

*Islands*

# Chromaticity

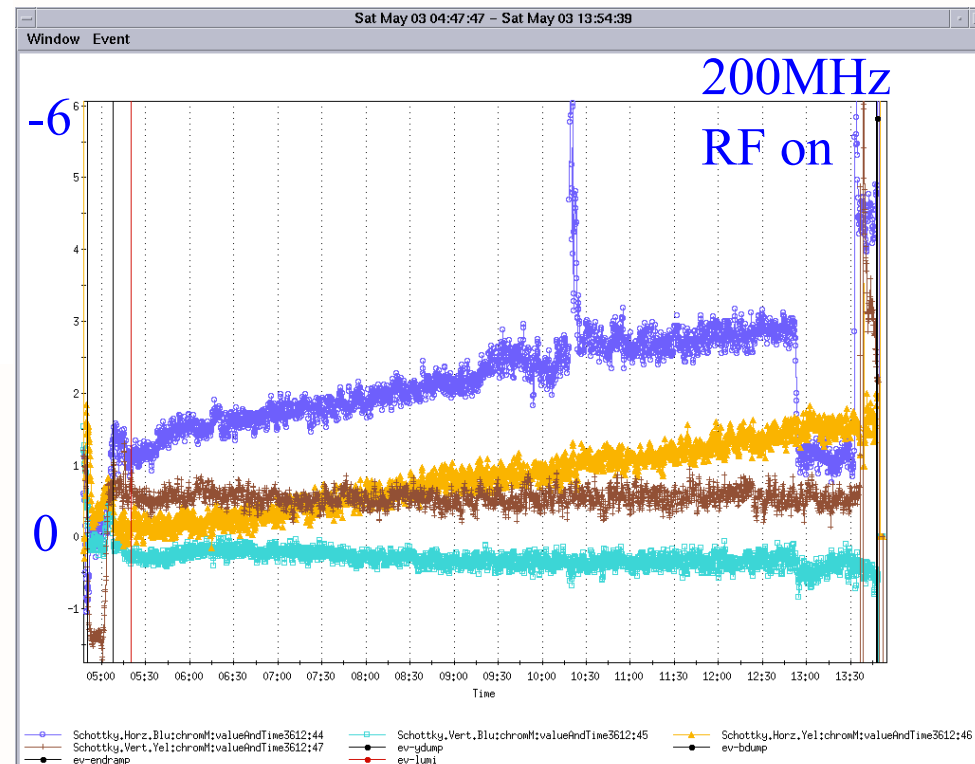
HALO'03



Chromaticity thru an 8hr store  
from Schottky

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Chromaticity from kicked and  
PLL tunes



# Fit Dependence of Chromaticity

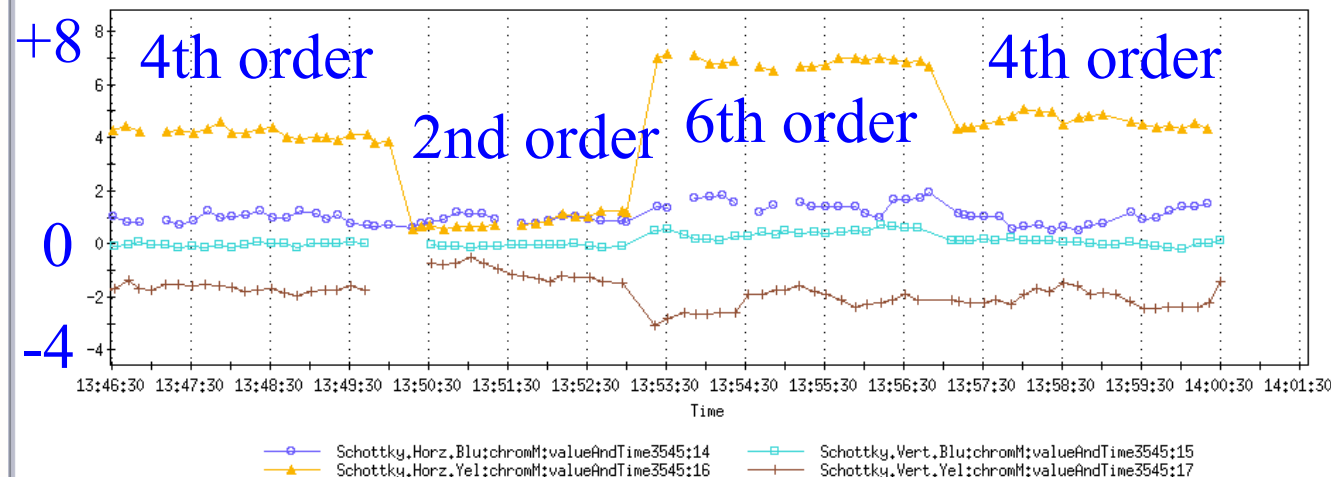
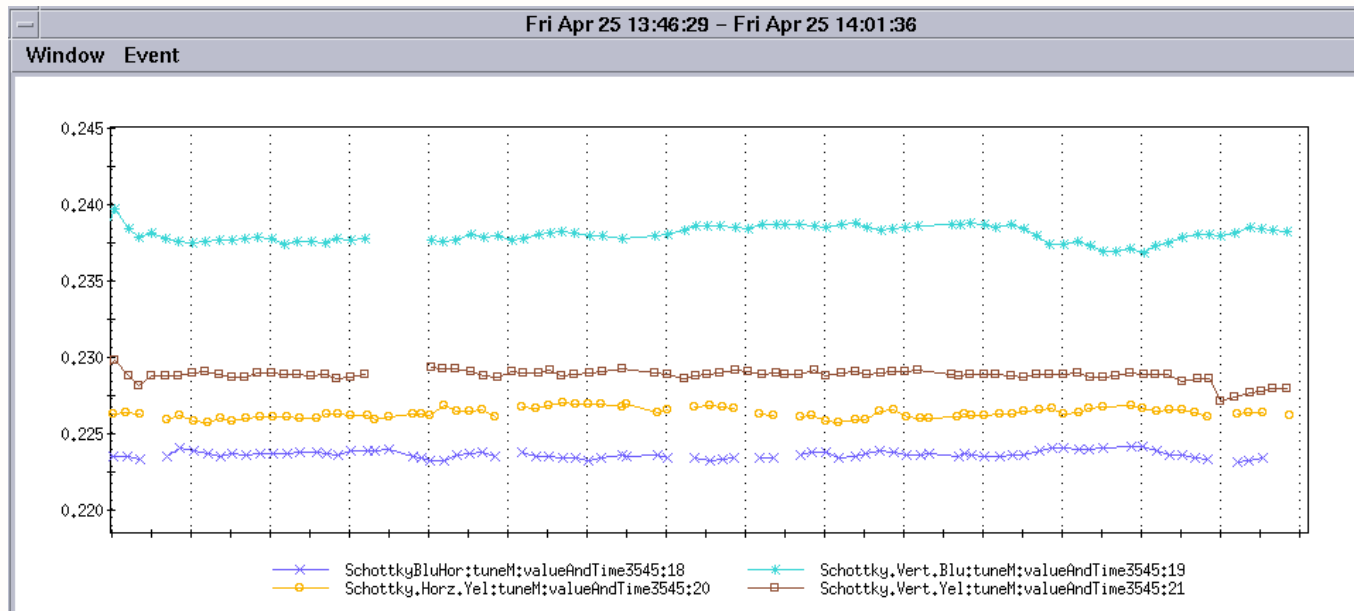
HALO'03

.24

.23

.22

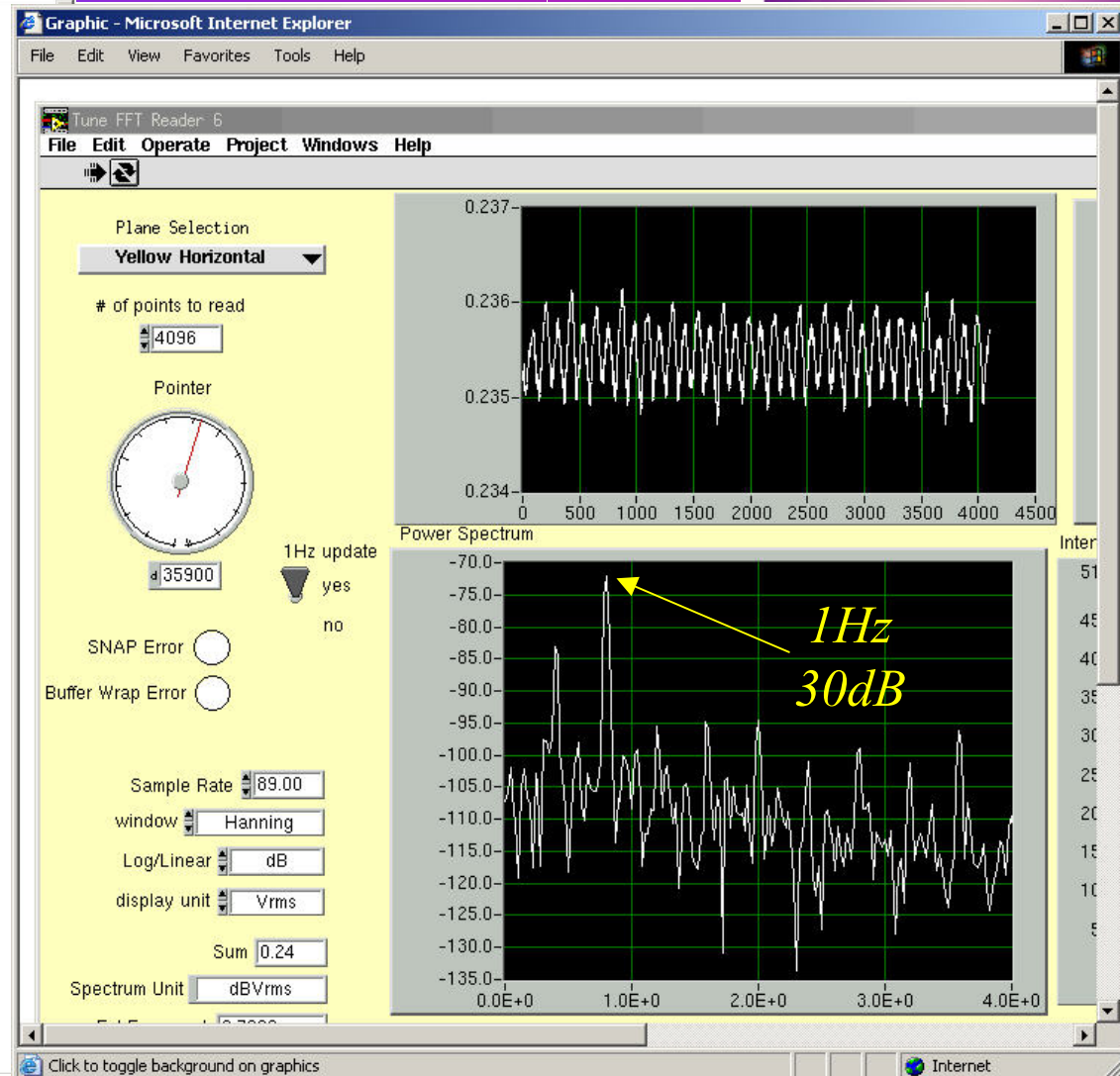
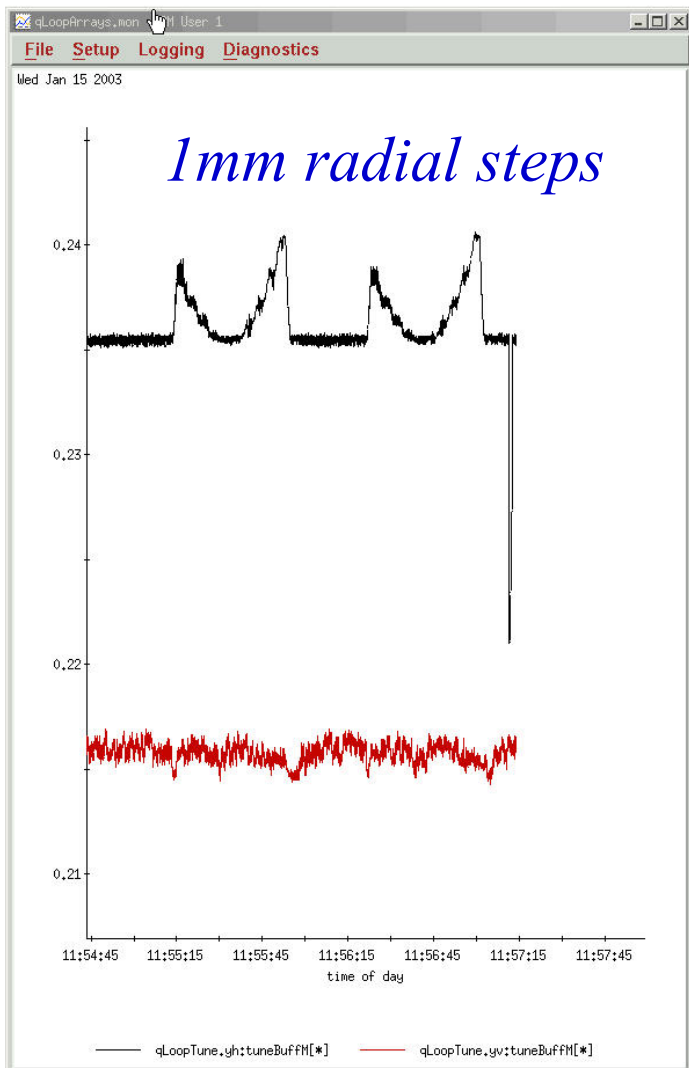
tune



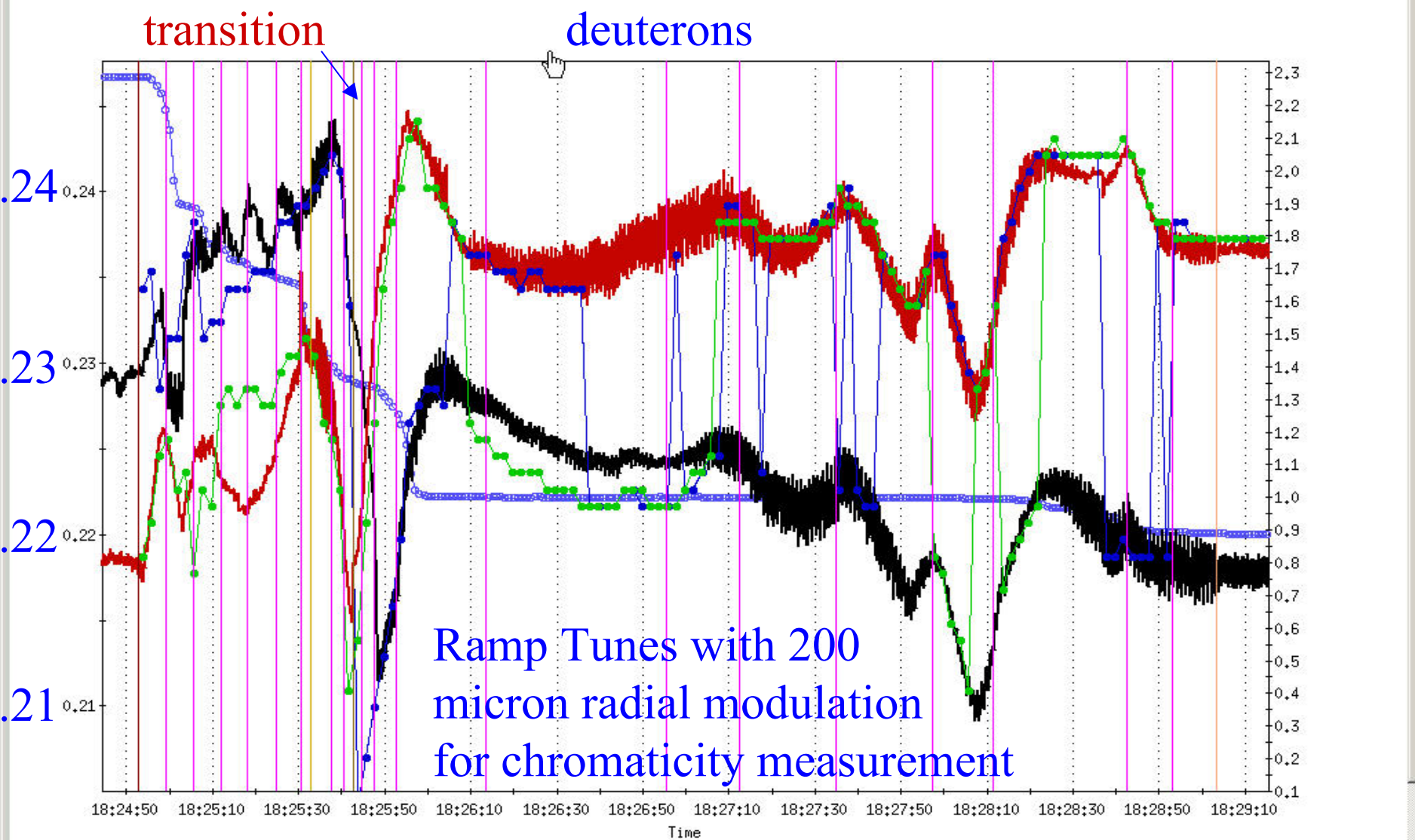
chromaticity

# Non-linear chromaticity – two methods

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*Radial modulation - .5Hz, .4mm*

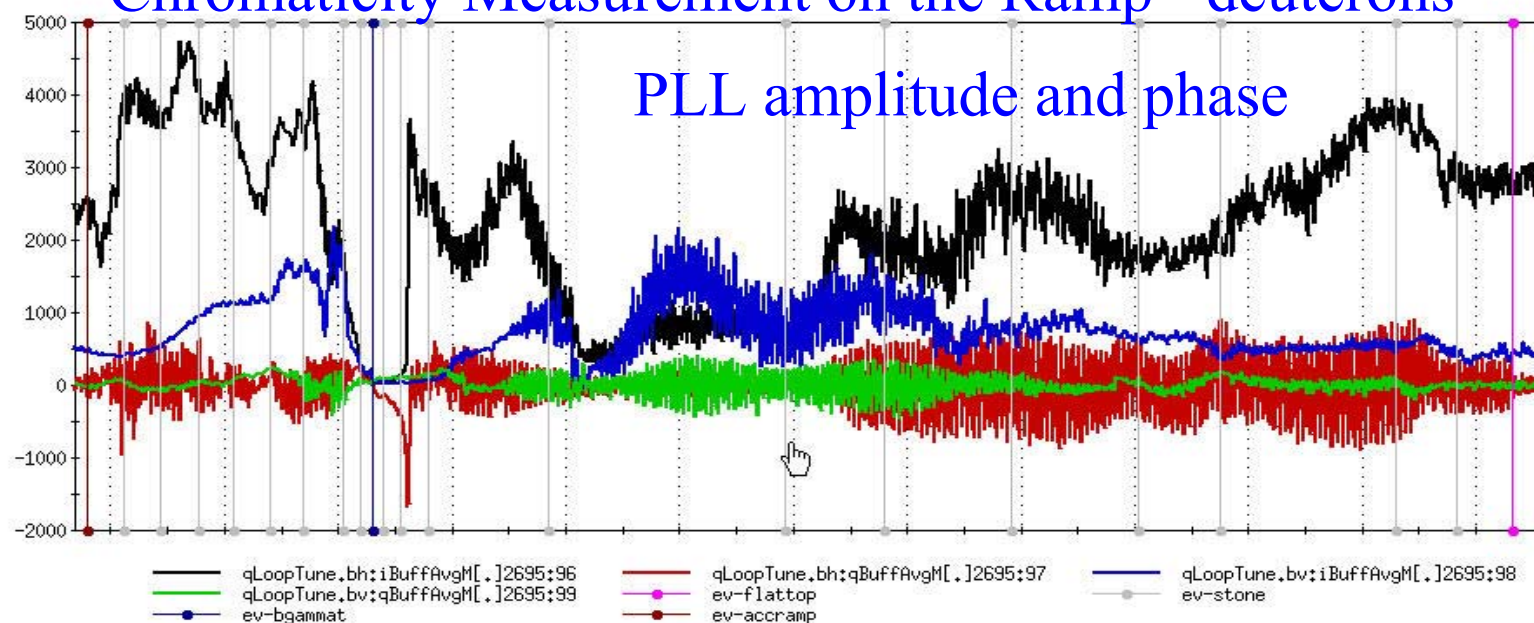


- |  |  |  |
|--|--|--|
| — qLoopTune, bh; tuneBuffM[.], 2685:0 (Y1)   | — qLoopTune, bv; tuneBuffM[.], 2685:1 (Y1) | — B, horizontal, tune, .1st, peak, 2685:2 (Y1) |
| — B, vertical, tune, .1st, peak, 2685:3 (Y1) | — ev-accramp (Y1)                          | — ev-stone (Y1)                                |
| — ev-bgtstart (Y1)                           | — ev-bgammat (Y1)                          | — ev-ygtstart (Y1)                             |
| — ev-ygammat (Y1)                            | — ev-flattop (Y1)                          | — bluDCCtotal-Deuterons2685:8 (Y2)             |

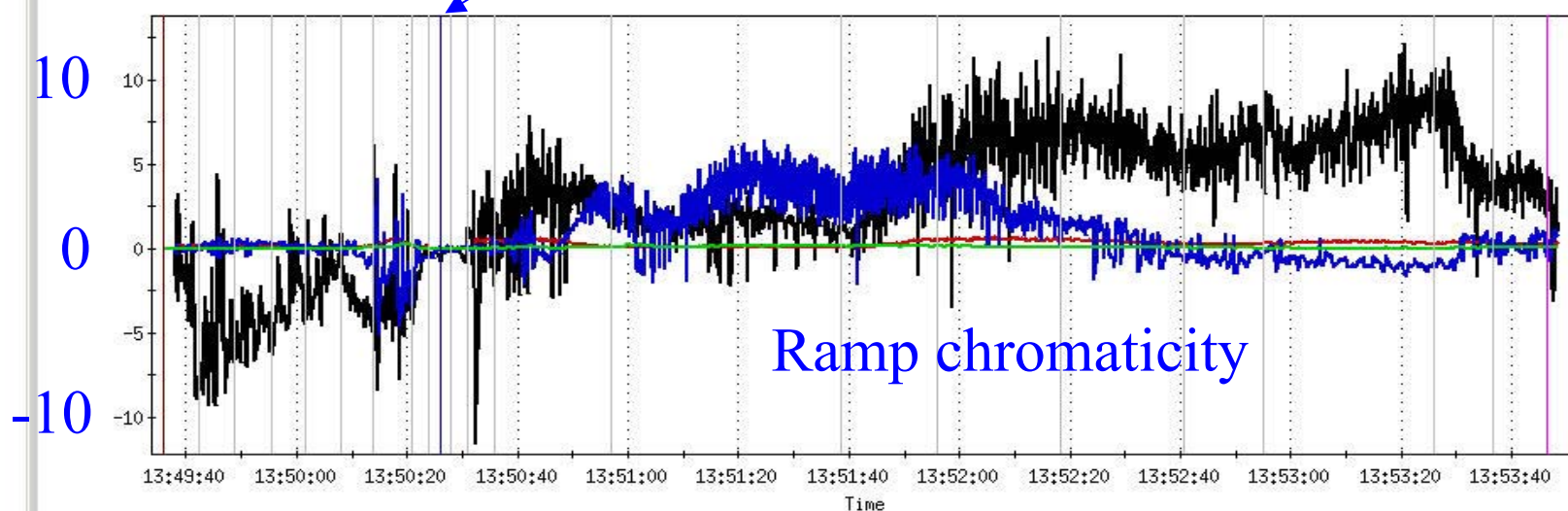


# Chromaticity Measurement on the Ramp - deuterons

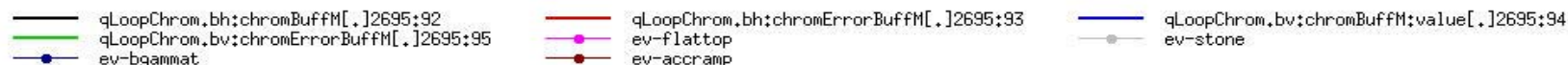
## PLL amplitude and phase



transition



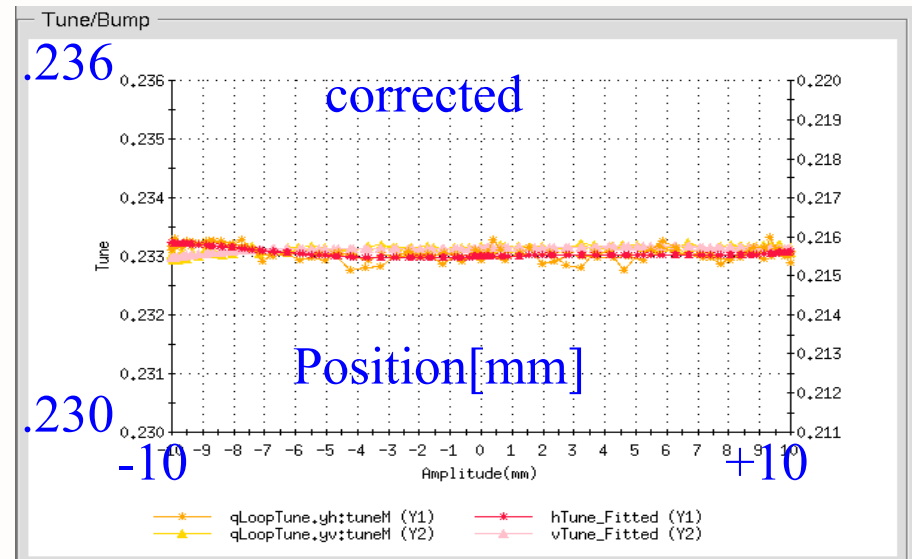
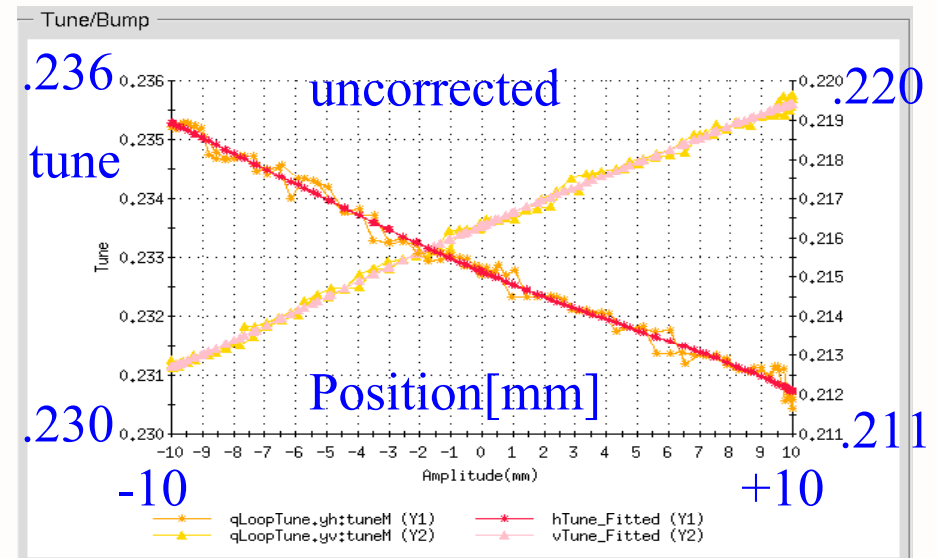
## Ramp chromaticity



# Nonlinearity Correction

HALO'03

- F. Pilat - PAC2003
- Purpose - improve dynamic aperture
- IR Triplet quads are main source of nonlinearity
- Method - measure tune while ramping a bump in the triplet, adjust correctors



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# *Resonances*

HALO'03

*What drives beam into Resonances?*

- Tune
- Space Charge
- Chromaticity (tune spread)
- Non-linearities
- **Coupling**
- ???

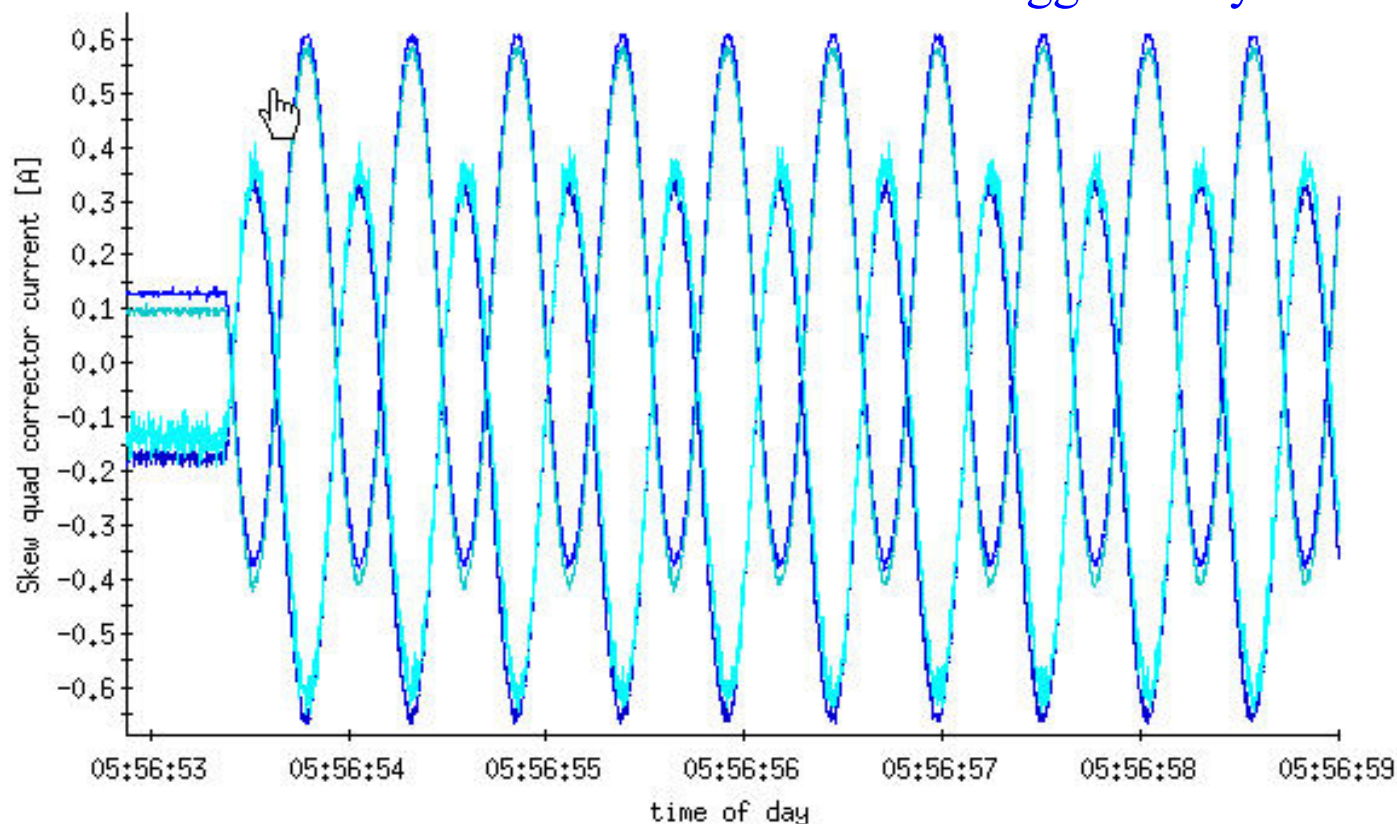
*Islands*

**File Setup Logging Diagnostics**

Wed Jan 22 2003

Blue skew quadrupole (families)

Suggested by T. Roser



2Hz skew quad modulation, two families, 180 deg phase

— bi1-qs-ps.current      - - - bo2-qs-ps.current  
— bo7-qs-ps.current      - - - bi8-qs-ps.current

&lt;

&gt;

**Message Area****Start**

Close

Duplicate





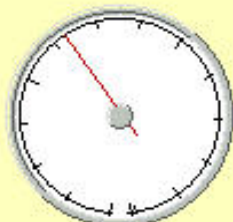
Plane Selection

Blue Horizontal

# of points to read

2048

Pointer



26292

1Hz update



yes

no

SNAP Error



Buffer Wrap Error



Sample Rate 89.00

window Hanning

Log/Linear dB

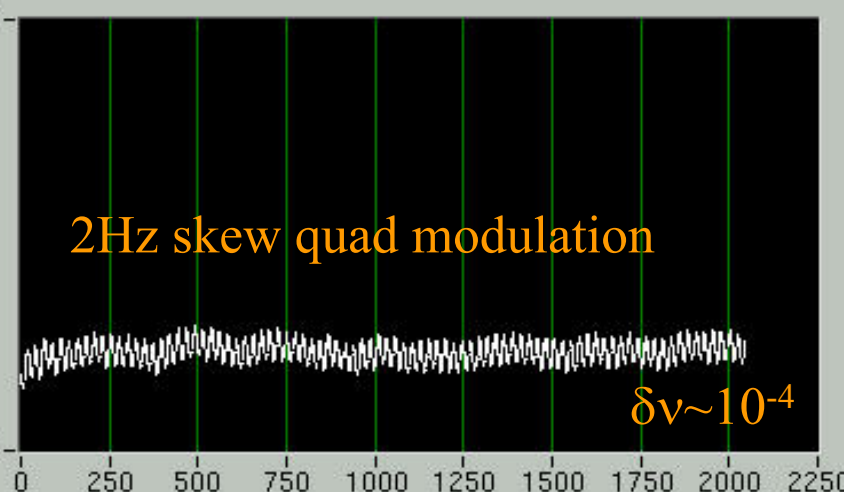
display unit Vrms

Sum 0.25

Spectrum Unit dBVrms

0.247-

0.246-



Power Spectrum

-90.0

-95.0

-100.0

-105.0

-110.0

-115.0

-120.0

-125.0

-130.0

-135.0

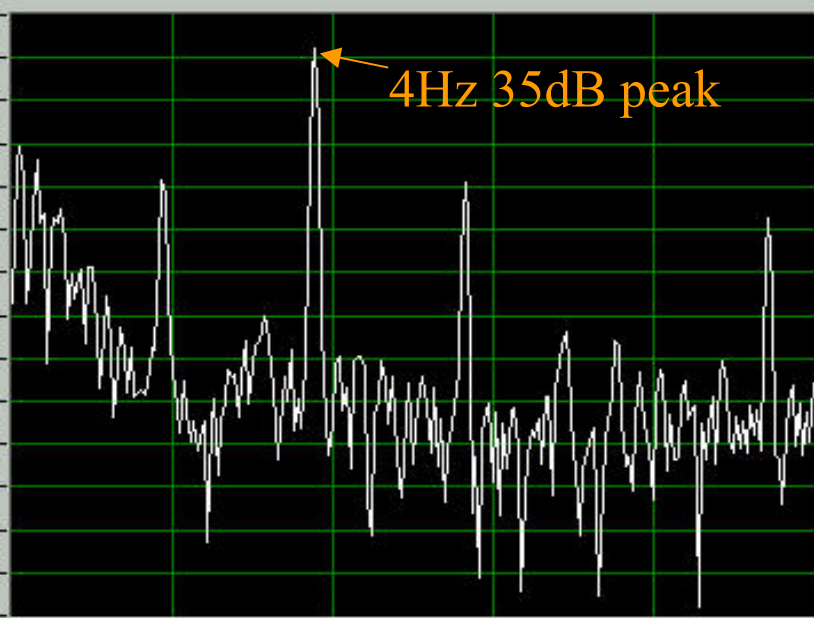
-140.0

-145.0

-150.0

-155.0

-160.0



0 Hz

10 Hz

Intensi

550

500

450

400

350

300

250

200

150

100

50

0

# *Resonances*

HALO'03

*What drives beam into Resonances?*

- Tune
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- Chromaticity (tune spread)
- Non-linearities
- Coupling
- ???

*Islands*



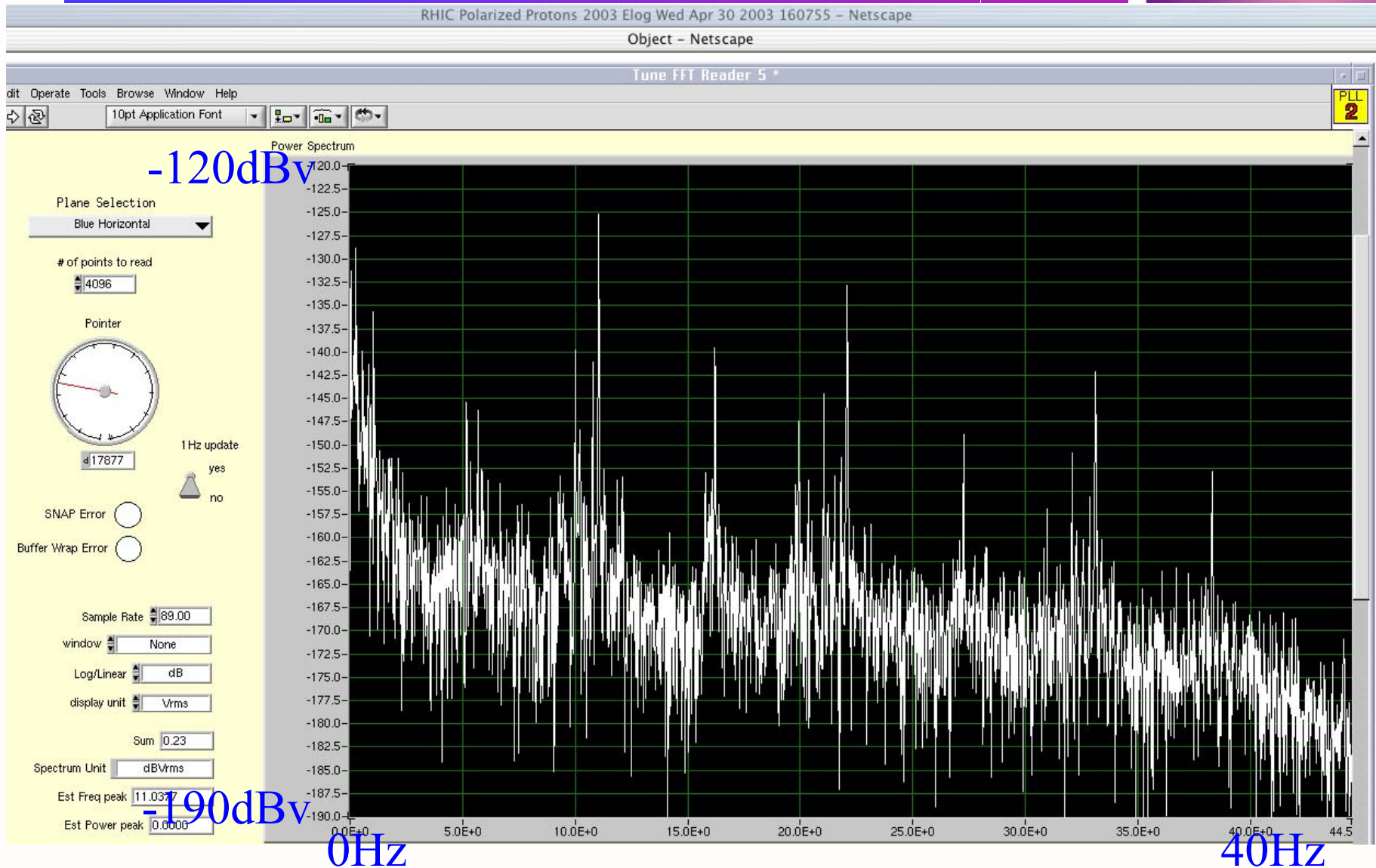
# *Digression to Islands*

HALO'03

- Island tune is precise – narrowband measurement
- Amplitude is large – power goes as square
- Power spectral density -  $S/N \sim N^2 x^2 / \delta f$  (coherent)
  - Inside separatrix  $N \sim 10^{11}$ ,  $x \sim 0.5\text{mm}$ ,  $\delta f \sim 1\text{KHz}$
  - Fraction excited by PLL  $\sim$  a few percent
  - In island  $N \sim 10^7$ ,  $x \sim 5\text{mm}$ ,  $\delta f \sim 10\text{Hz}$
- Down 40dB, island  $N \sim 10^7$  (coherent)
- Experience – PLL locks on islands in RHIC

# 'Typical' PLL FFT

HALO'03

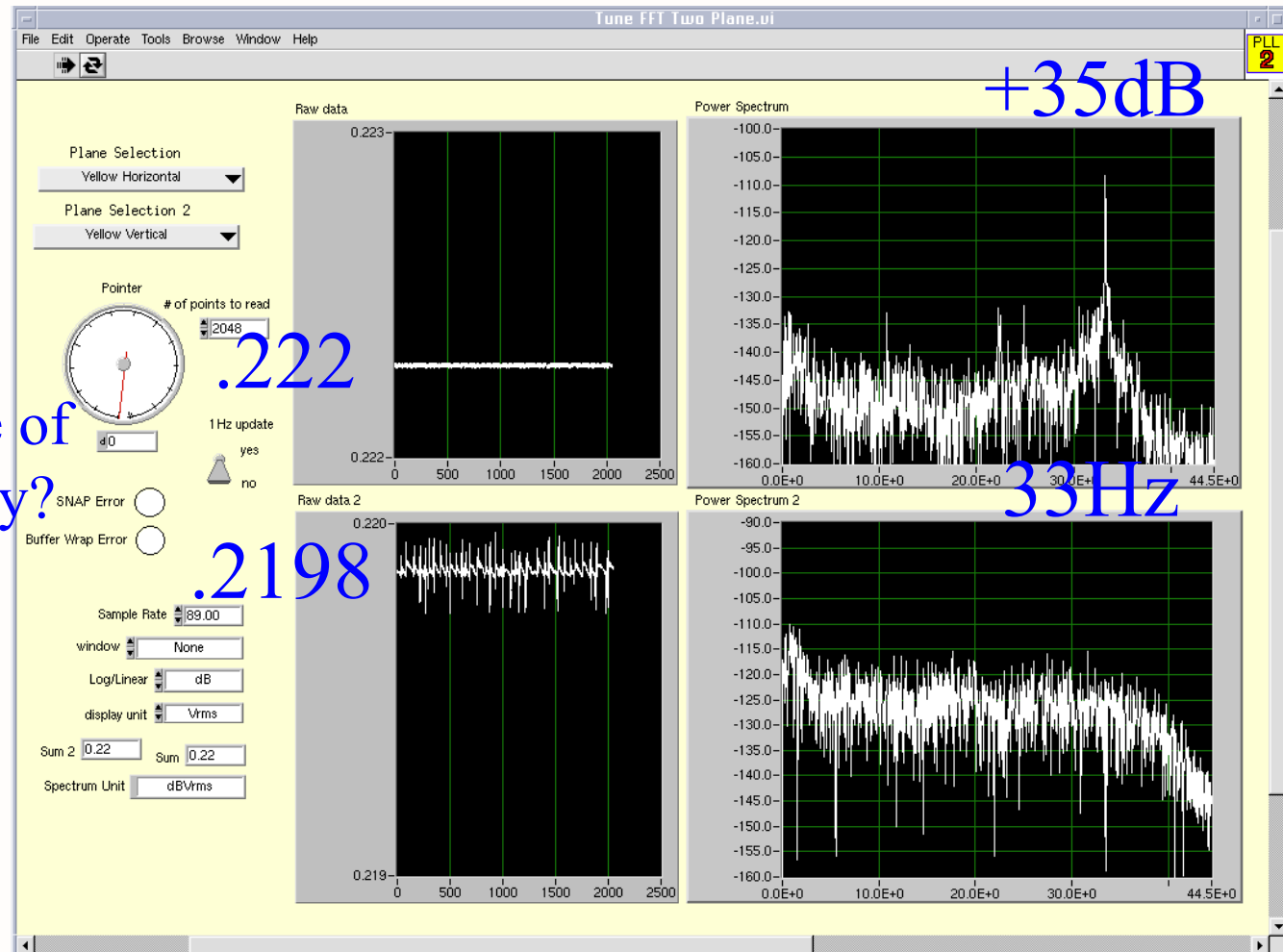


# Island at 2/9 in RHIC?

HALO'03

Kickers off

Position dependence of  
excitation frequency?  
resonance  
compensation?



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# *‘Applicable’ Mechanisms*

HALO'03

- Mismatch
- Resonances
- **e-cloud effects**
- Instabilities
- Beam-beam
- Tune modulation

*fast*

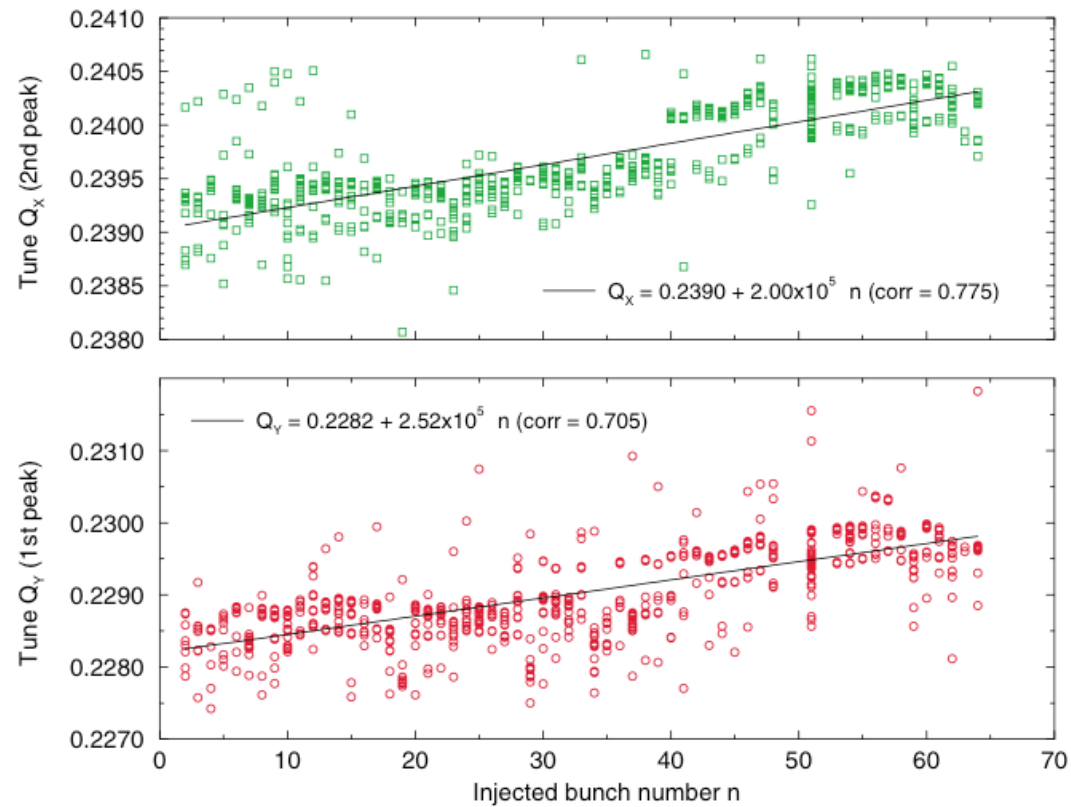
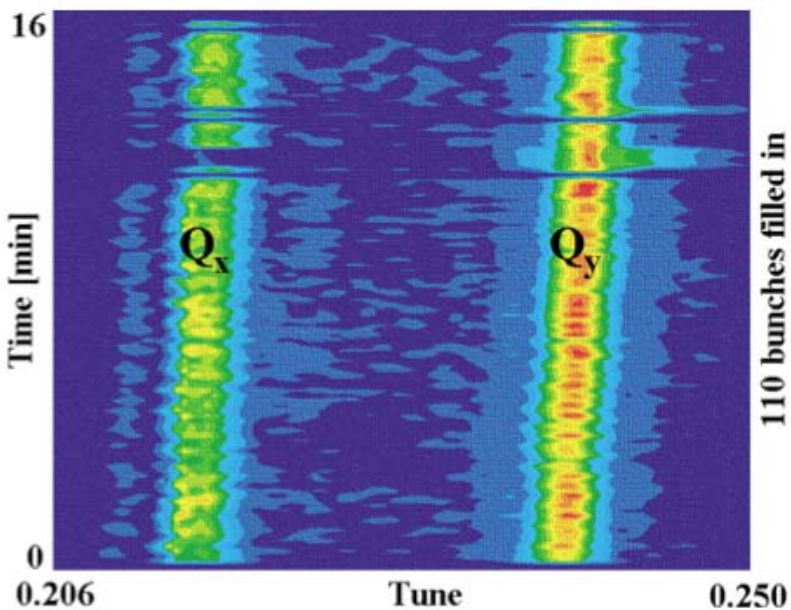


*slow*

# *e-cloud coherent tune shift*

HALO'03

W. Fischer et al



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# *‘Applicable’ Mechanisms*

HALO'03

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- **Instabilities**
- Beam-beam
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*fast*



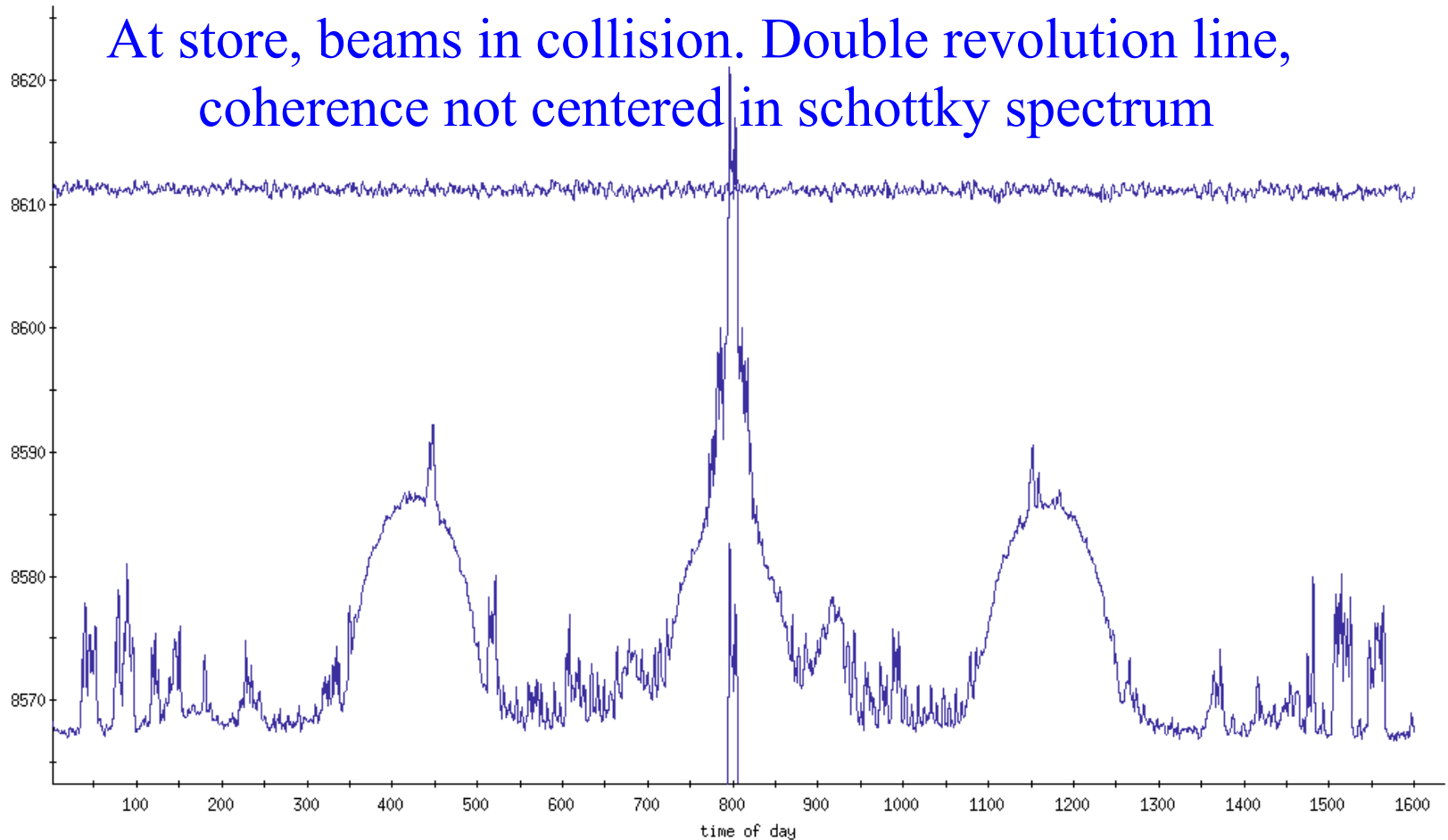
*slow*



# Schottky Coherence

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At store, beams in collision. Double revolution line, coherence not centered in schottky spectrum



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# *‘Applicable’ Mechanisms*

HALO'03

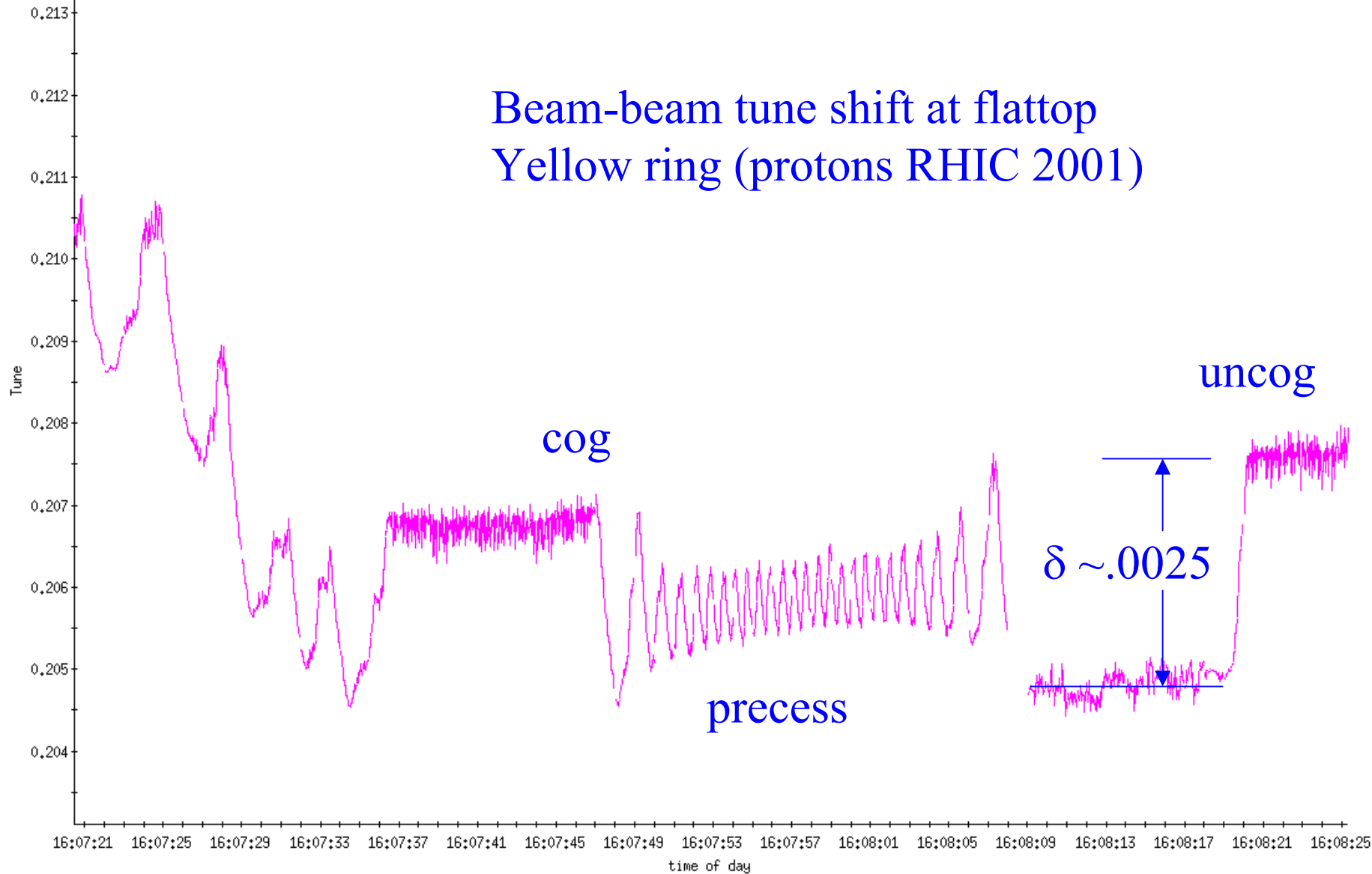
- Mismatch
- Resonances
- e-cloud effects
- Instabilities
- **Beam-beam**
- Tune modulation

*fast*



*slow*

# Beam-beam tune shift at flattop Yellow ring (protons RHIC 2001)



# *‘Applicable’ Mechanisms*

HALO'03

- Mismatch
- Resonances
- e-cloud effects
- Instabilities
- Beam-beam
- **Tune modulation**

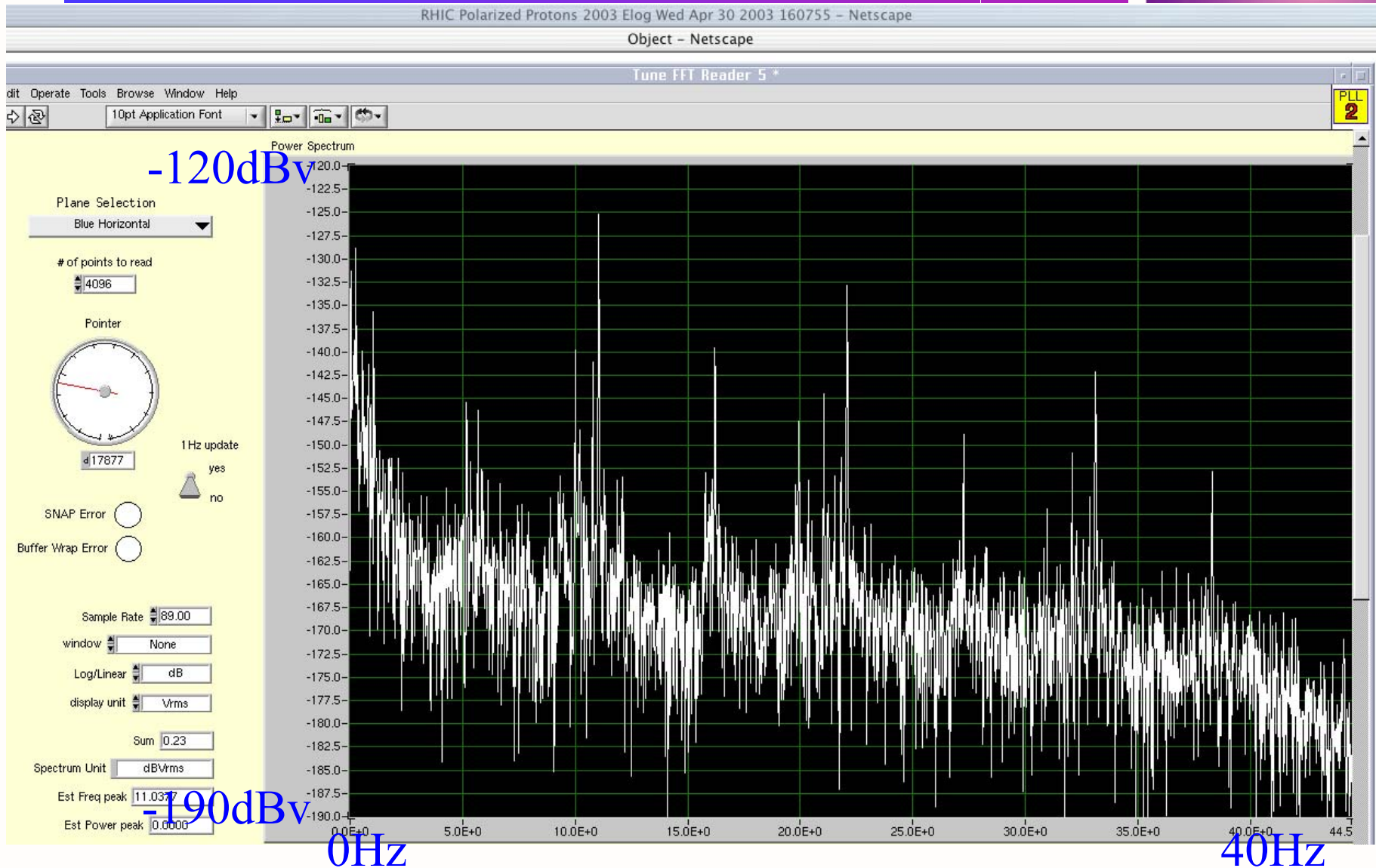
*fast*



*slow*

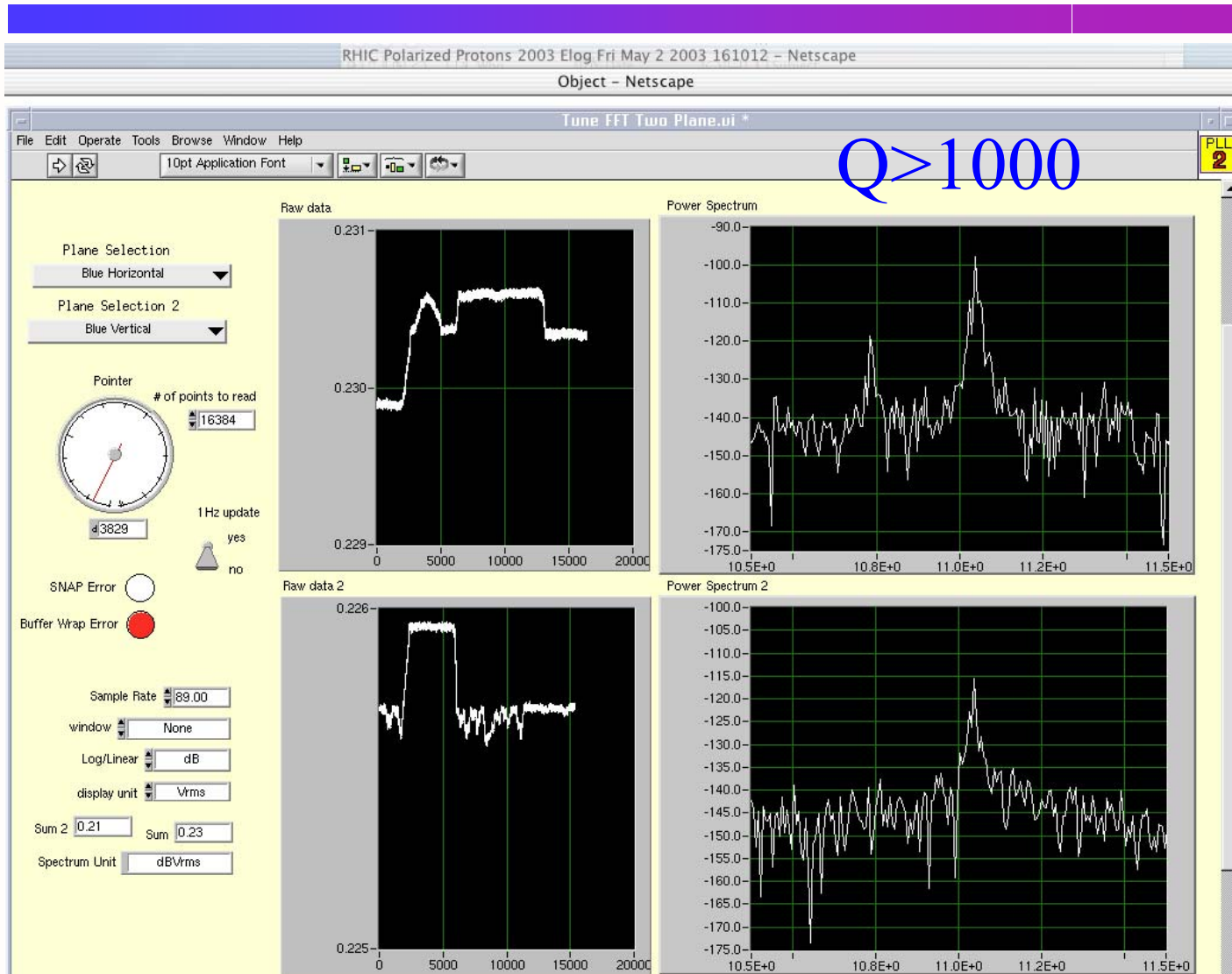
# 'Typical' PLL FFT

HALO'03



# Zoom on 11Hz Line

HALO'03



-90dBv

-175dBv

10.5Hz

11.5Hz



# *Kinds of Tune-based Tools*

HALO'03

- Tools to **Diagnose** Halo-forming conditions
- Tools to **Avoid** Halo formation
- Tools to **Diagnose** existing Halo
- Tools to **Remove** Halo
  - Gap cleaning
  - Halo cooling
  - ???

# Emittance and $\Delta p/p$ thru 16hr store

HALO'03



# Conclusions

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HALO'03

- A variety of tune-based tools exist to **Diagnose** and help **Avoid** Halo-forming conditions
- Tune-based tools to **Diagnose** existing Halo are difficult, but possibilities exist
- We are looking for ideas